SW06 Shallow Water Acoustics Experiment

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LONG TERM GOALS

The long term goal of our shallow water acoustics work is to understand the nature of low frequency (10-1500 Hz) acoustic propagation and scattering in shallow water when strong oceanic variability in the form of fronts, eddies, boundary layers, and internal waves is present. To achieve this goal, we participated in a scientifically sound and Navy relevant basic research experiment in shallow water acoustics, concentrating on both low and medium frequencies.

OBJECTIVES

Our primary objectives this year were to: 1) do final planning and preparation for a large scale shallow water acoustics experiment in 2006, which combines low-frequency and medium-frequency acoustics work, 2) execute the experiment, and 3) begin analysis of the data collected by the experiment. A secondary objective was to continue some of our ongoing analyses in shallow water acoustics, both in data analysis and theory.

APPROACH

Our approach to planning the SW06 experiment included: 1) organizing and participating in large ONR workshops that involved all the SW06 components and PI's (including the LEAR, NLIWI, and AWACS components), 2) organizing the at-sea plans for the SW06 experiment, including ship schedules, equipment positions, deployment and recovery timetables, logistics, etc. and 3) organizing data communications for the experiment, including the web site. This was done in close collaboration with Dr. Dajun Tang of APL/UW (Co-Chief Scientist on the experiment) and the ONR-OA Program Managers.

In preparing for the experiment, we constructed and tested ~ 40 oceanographic moorings, 5 large source moorings, a large HLA/VLA mooring, 5 SHRU's (single hydrophone receiver units), a REMUS AUV thinline towed acoustic array system, a smaller VLA receiver unit, and assorted other equipment. A significant fraction of the equipment for this experiment was funded through the ONR DURIP initiative.

In the performance of the experiment, the WHOI group participated in three large scale cruises: two mooring (deployment/recovery) cruises on the R/V Knorr and one vehicles/adaptive ocean/acoustic sampling cruise on R/V Endeavor.

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In performing the data analysis, we are doing preliminary "first looks" at the data and post-calibrations of the instruments (where necessary). We hope to be able to have some large scale meetings of all the SW06 PI's in the not-too-distant future to coordinate the analysis efforts for this extremely large and rich data set.

WORK COMPLETED/ACCOMPLISHMENTS

Our biggest accomplishment was the very successful execution of the SW06 experiment. For the moored component, we deployed 57 long term acoustics and oceanography moorings, and (with the discovery of our last SHRU by a Virginia fisherman) at the end successfully retrieved all the moored equipment back. Of equal importance, it seems that all the equipment worked and produced first-rate data. We thus have an incredibly rich data record. Moreover, all the other components of the SW06 program worked, so that the combined data sets should produce a "whole that is far greater than the sum of the parts", to use an old but relevant phrase. An example of some of the acoustic data is shown in Figure 1 below.

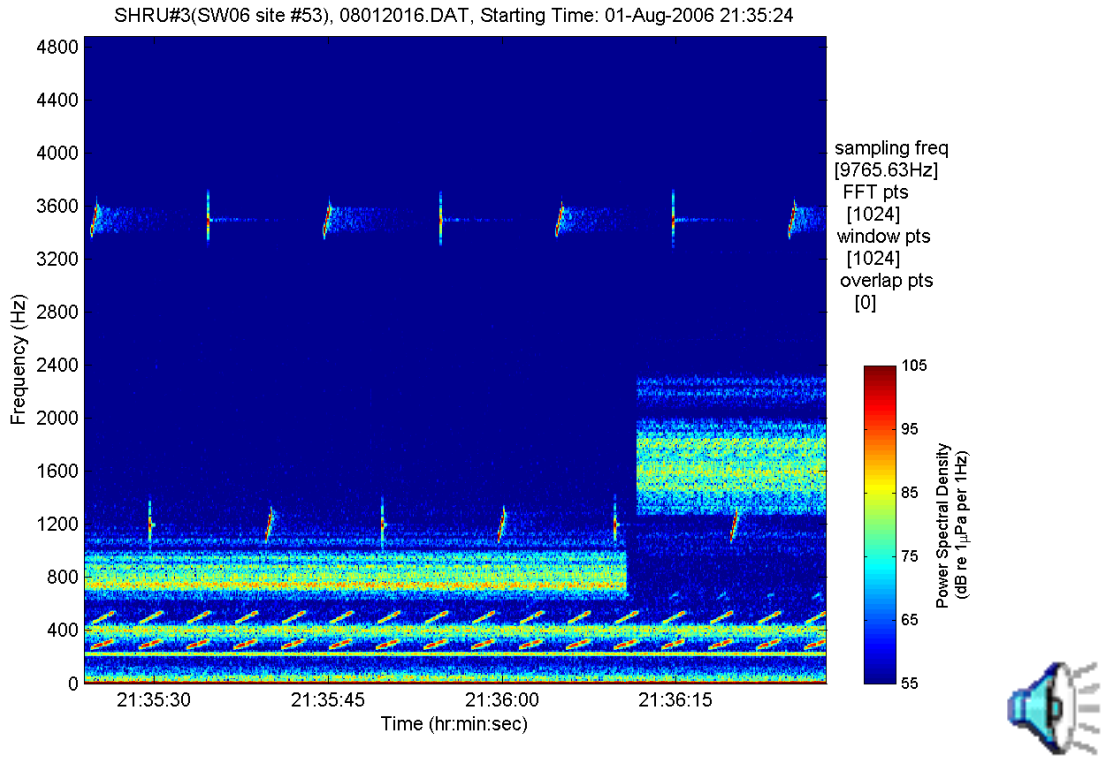

Figure 1. SHRU data from SW06, showing receptions from 224 Hz, 300 Hz, 400 Hz, 500 Hz, 800 Hz, and 1600 Hz moored sources, and 1200 Hz and 3600 Hz A-Comms signals sent from a shipboard source.

The oceanography component, which is "support" from the strictly acoustics viewpoint, was also quite successful, and we have ~50 moorings with oceanographic data that will be very important in understanding the acoustics records.

The vehicles and adaptive sampling part of our SW06 deployment was partially successful. Weather prohibited us from doing the small boat operations that were needed to deploy the small REMUS

AUV's and the glider, to our distress. However, this also told us where we needed to improve the system, and we are currently looking into doing so. On the other hand, we had very good success looking at adaptive acoustic/oceanographic sampling using a combination of Scanfish surveys, OMAS mobile acoustic sources, and advanced sonobuoys. Again, a rich data set was obtained.

We also worked on a number of other shallow water acoustics topics this past year, in addition to SW06. These were: 1) ducting of acoustic energy between internal waves in shallow water, 2) attachment of a low frequency towed array to the small REMUS AUV (in conjunction with our AWACS efforts), 3) studies of the uncertainty in bottom inversions due to water column uncertainty, 4) an overview article on nonlinear internal waves, and 5) a book on shallow water acoustics. This work has resulted in a number of publications as cited below.

RESULTS

The result that we have to date re the SW06 experiment is a very large, rich data set. We are just "dumping" the data from the instruments now, and storing it on safer media. As concerns the other analysis efforts, those results are best seen through the papers listed below.

IMPACT/APPLICATIONS

The impact of our experiment should be: 1) an increased understanding of the propagation of sound through complicated coastal oceanography, 2) a better understanding of how to incorporate "uncertainty" in the ocean state into sonar performance measures, and 3) an improved use of AUV's in doing acoustic missions in coastal regions, eventually giving the Navy a "robotic forward area presence."

TRANSITIONS

One eventual transition of our data will be to ONR's Uncertainty DRI program, where the interest is in "the error bars" in ocean acoustic field and system performance prediction. We also hope to have our REMUS acoustic towed array technology transitioned to operational use in the future.

RELATED PROJECTS

The SWARM acoustics/internal wave study, the PRIMER acoustics/shelfbreak front study, and ASIAEX were direct predecessors of SW06, and examined some of the same acoustic scientific issues, only with far fewer measurement resources. The "Non-linear internal waves initiative" (NLIWI) is strongly related to our SW06 LEAR effort via the environmental support that the oceanographic moorings (and other PO measurements) provided. The SW06 experiment also had an AWACS component, stressing the use of acoustics on AUV's and gliders, and also adaptive sampling.

PUBLICATIONS

[1] J.Apel, L. Ostrovsky, Y. Stepanyants, and J. Lynch, "Internal solitons in the ocean and their effect on underwater sound", submitted to *J. Acoust. Soc. Am.* (2006)

[2] J. Holmes, W. Carey, and J. Lynch, "Results from an autonomous underwater vehicle towed hydrophone array experiment in Nantucket Sound", in press *J. Acoust. Soc. Am.- EL* (2006).

[3] E. Sullivan, J. Holmes, W. Carey, and J. Lynch, "Broadband passive synthetic aperture: experimental results." In press *J. Acoust. Soc. Am.- EL* (2006).

[4] B. Katznelson, V. Petnikov, and J. Lynch, "Shallow water acoustics", book submitted to Springer Verlag editorial board, 630 pages. (2006)

[5] J. Lynch, B. Katznelson, and M. Orr, "Low frequency acoustic propagation through shallow water internal waves." Book chapter submitted to Cambridge University Press. (2006).

PUBLICATIONS (non-refereed)

[1] Jason D. Holmes, William M. Carey, James F. Lynch. "Results from the Nantucket Sound autonomous underwater vehicle towed hydrophone array experiment" Proceedings IEEE OES Oceans 06 Boston, September 2006

[2] James Lynch, D. Chu, T. Austin, W. Carey, A. Pierce, and J. Holmes, "Detection and classification of buried targets and sub-bottom geoacoustic inversion with an AUV carried low frequency acoustic source and a towed array." Proceedings IEEE OES Oceans 06 Boston, September 2006

HONORS/AWARDS/PRIZES

J. Lynch was made Adjunct Scientist at Boston University and Rensselaer Polytechnic Institute this year.